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RESEARCH ON SEMICONDUCTORS # 19

Bardeen

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1. PROJECT STATUS AND FUTURE PLANS

1.1 Tunneling Experiments

H. Pao has temporarily left the contract as of June 1, 1963 and will return at the beginning of the fall semester, September 1963.

1.2 The Selenium - Tellurium Alloy System - P. Lanyon

In the present quarter attention has been concentrated on the properties of selenium-tellurium alloys. As has been reported previously in Status Reports #17 & #18 it has not been found possible to produce a disordered sample of the alloys by quenching a bulk sample if the tellurium concentration exceeded 50 atomic percent. With evaporated layers disordered alloys have been prepared containing up to 65 atomic percent of tellurium. Such layers convert to the ordered form with time. It has been found that the rate of conversion of the layers depends markedly on the temperature and on their composition. With SeTe (equal atomic proportions of selnium and tellurium) the alloy is reasonably stable at room temperature and only converts to the ordered form above 60°C. On the other hand the alloy Se_7Te_{13} converts to the ordered form at room temperature within a few minutes of preparation. This agrees with the observations made on the bulk alloys and is consistent with the fact that tellurium exists in only one allotropic form whereas selenium exists in the two forms with chains. The apparatus is being redesigned to make practical measurements at low temperatures on the alloys containing higher tellurium concentrations. It is hoped that the disordered forms of the alloys may be more stable at these lower temperatures so that the conversion to the ordered form may be observed. Measurements on the alloys have fallen into two distinct groups - electrical and optical measurements. X- ray measurements are being started to determine whether there is a change in structure on conversion.

1.2.1 Electrical Measurements

Most of the measurements have been made on the alloy SeTe, although some measurements have also been made on Se_7Te_{13}. If SeTe is heated above 60°C conversion takes place. At first there is no apparent result of the heat treatment, but after some time the resistance starts to drop slowly. The speed of conversion increases to maximum rate on a log-linear scale and then diminishes as

as the film approaches its final equilibrium state. Typically the ratio of the resistance before conversion to that after conversion is about 10^5. It seems reasonable to associate the conversion process with an ordering of the chains since this is known to occur with pure selenium. From the temperature dependence of the maximum rate of conversion it appears that with SeTe the process controlling the conversion has an activation energy of about 1 eV. The conductivities before and after conversion both depend exponentially on temperature, the activation energies being about 0.5 eV and 0.23 eV respectively. The final value of the resistance agrees well with that calculated using the measured value of ρ in the bulk ordered specimens.

Measurements have also been made on layers of Se_7Te_{13}. With this alloy conversion takes place at room temperature. At present it is impossible to start measurements less than 30 minutes after the preparation of the layers at which time the resistance is altering in the ratio e:1 in about 6 minutes. With the new gear it will be possible to evaporate onto a cooled substrate and to make the measurements immediately. It is hoped to extend the measurements to alloys with an even higher tellurium concentration.

Preliminary measurements have also been made of the Hall mobility in the thin ordered layers. The value for SeTe is of the order of 10 cm^2 / V-sec. It appears that the mobility decreases below room temperature. Further measurements will be required to confirm this.

1.2.2 Optical Measurements

Together with the change in electrical properties on conversion there is also a change in the absorption spectrum. The optical density at photon energies above the absorption edge increases. In addition the absorption continues to much lower photon energies than before conversion. The absorption spectrum is being checked at various stages in the conversion process, as revealed by the change in resistance. This has shown that the change is a continuous process. It is planned to continue this study during the next quarter.

1.3 Thin Films of Magnesium on Magnesium Oxide - John Moore

Measurements of conductivity vs. temperature were made on thin films of magnesium deposited on a magnesium oxide substrate at room temperature. It was found that a resistance of 10^8 ohms across the long dimension of the sample

8 mm x 2 mm produced a faintly cloudy surface. Cooling to liquid nitrogen temperature increased the resistance four to five orders of magnitude. Magnetoresistance and Hall measurements were inconclusive.

The latest tube made has a thermocouple placed near the sample so that better measurements of resistance vs. temperature can be made. Unfortunately it has two noisy contacts so that Hall measurements can't be done. Films with a resistance of 10^7-10^8 ohms were deposited at liquid nitrogen temperature. With these films the crystal appears perfectly transparent. These films are ohmic and stable at low fields (less than one volt/cm) for periods of at least 1 1/2 hours. They remain stable on heating to about -140°C where the resistance has decreased by a factor of three. Further heating causes the resistance to increase with temperature, and on heating to room temperature the film resistance approaches 10^{13} Ω. At no constant temperature point greater than -140°C did the film resistance reach an equilibrium (20-30 min at const T), but rather the resistance was observed to increase steadily at a very slow rate.

2. PERSONNEL

Name	Position	Percent of Time
Dr. John Bardeen	Professor	no cost to project
Paul Handler	Associate Professor	15 December-31 January 50%
		1 February-15 March 25%
Hubert P. D.Lanyon	Visiting Research Associate	100%
W. E. Miller	Professor	5%
John S. Moore	Research Assistant	50%
Kenry Pao	Research Assistant	50%
C. H.Sah	Associate Professor	25% (January 1-February 1 only)